

## Lunar Laser Ranging Trial at Koganei SLR station Lunar Laser Ranging Trial at Koganei SLR station

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**Introduction:** The Lunar Laser Ranging (LLR) is a technique to measure the distance between laser stations on the Earth and retroreflectors on the Moon, by detecting the time of flight of high-powered laser emitted from the ground station. Since the Earth-Moon distance contains information of lunar orbit, lunar solid tides, and lunar orientation and rotation, observation data of LLR have contributed to the lunar science, especially for the estimation of the inner structure of the Moon through orientation, rotation and tide. There are five retroreflectors on the Moon, Apollo 11, 14, 15 (U. S. A.), Lunokhod 1 and 2 (french-made, carried by former U. S. S. R.). The Apollo 15 has largest aperture among them, and almost 75 % of the total LLR data are from Apollo 15 site.

**System Description:** Since there is no Japanese station which can range the Moon so far, a precursor ranging experiment by using the Satellite Laser Ranging (SLR) facility in the NICT Koganei campus in Tokyo is ongoing. The SLR station has a 1.5 m Cassegrain telescope with Coude focus. Normally it is equipped with a laser with 20mJ, 20Hz repetition rate, and 35 picoseconds pulse width for satellite ranging. In addition to it, a wide-pulse width laser (3 nanoseconds, which corresponds to 45 cm in 2-way range) with energy of about 350 mJ per shot, repetition rate of 10Hz, wavelength of 532 nm is introduced to detect photons from the lunar retroreflectors for demonstration. As the pulse width is broad, the high accuracy ranging is not expected, therefore it is solely used for the confirmation of the optical link budget between the ground station and retroreflectors on the Moon. As the photon detector, we use a SPAD (Single Photon Avalanche Diode) and also an MCP (Micro Channel Plate) photo multiplier whose quantum efficiency is twice as much as that of the SPAD in use. For the pointing, a CCD imager is also available in the same detector box. They can be switched by reflecting mirrors. To suppress the background noise, a bandpass filter (0.3 nm FWHM, 50 % transparency) and spatial filter (pinhole) with diameter of 400 microns are installed and checked. For better link budget, the contamination of optical elements of the telescope and on the optical bench was checked. The alignment of the laser emission path with respect to the laser receiving path and laser beam divergence has been adjusted to maximize the efficiency of the laser emission.

**Pointing:** Because the retroreflectors are small and they are not visible from ground telescopes, we point the telescope to known small-sized craters (~10 km in diameter) whose positions are known in selenographic coordinate and thus in topocentric coordinate at the observation site. Then the offset angles in azimuth and elevation direction from the predicted pointing direction are determined so that the center of the crater comes to the center of the CCD images which are colligned with the SPAD and the MCP. This procedure confirms the pointing of the telescope.

**Observations:** Trials for the lunar return have been conducted since autumn 2013. As of the date of submission, the ranging to the Moon is not successful. Therefore we need to detect the return from the Apollo 15 site by using the nanosecond laser pulse for the first step. As the next step, we need to know the condition on which lunar ranging is successful in Koganei, for example, lunar phase, distance to the retroreflectors, libration angles, and atmospheric conditions.

**Keywords:** Lunar Laser Ranging, Satellite Laser Ranging, Moon, internal structure